Marijuana and e-cigarette use in a US national sample of 8th and 10th grade never-smokers of conventional cigarettes

Olusegun Owotomo
University of Texas at Austin, owotomo@utexas.edu

Julie Maslowsky
University of Texas at Austin, maslowsky@austin.utexas.edu

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Introduction

Marijuana use among adolescents is a pressing public health issue in the United States. In 2016, the prevalence of past 30-day marijuana use was 5.4% among 8th graders, 14% among 10th graders, and 22.5% among 12th-grade students.[1] Marijuana remains an illegal substance according to federal laws;[2] however, several states have legalized marijuana for medical and adult recreational use.[3,4] The spreading legalization of marijuana sales, with the attendant lowered perceptions of harm associated with marijuana use, may further increase the risk of adolescent marijuana use.[5] Further, the documented rising potency of marijuana may elevate the risk of addiction and worsen the consequences of marijuana use among adolescents.[6] These consequences include impaired cognitive and academic performance;[8-13] increased risk of mental health problems such as addiction, depression, and schizophrenia;[14-17] increased risk of motor vehicle accidents;[18,19] and increased propensity to progress to use of other illicit drugs.[20-23] In order to effectively prevent or address the public health issues presented by marijuana use, the predictors of marijuana use among adolescents must be identified.

E-cigarette use may predict marijuana use among adolescents. E-cigarettes are battery-powered forms of vaporizers that heat up liquids (such as nicotine, flavors, and hash oil) into aerosols and inhalable vapor.[24,25] Prior studies have established a direct association between conventional cigarette smoking and marijuana use.[25,26] However, over the past few years, e-cigarettes have become more popular than conventional cigarettes among US adolescents.[28,29] It is possible that adolescents transition directly from e-cigarette use to marijuana use because of their ability to "vape" marijuana or hash oil through e-cigarettes. In a recent national study, the prevalence of vaping marijuana among 8th- and 10th-grade students who reported vaping in the preceding 30 days was 9% and 11%, respectively.[24] The ability to conceal marijuana use from others is an important reason why youth vape marijuana through e-cigarettes.[30] Examining the relationship between e-cigarette and marijuana use among adolescents is paramount because of the current policy environment for both marijuana and e-cigarettes. For example, increasing legalization of marijuana sales and lack of restriction on e-cigarette advertising may potentially favor use of both marijuana and e-cigarettes.[3-5,31]

The concurrent use of marijuana and e-cigarettes among adolescents who have never smoked conventional cigarettes is plausible and warrants close monitoring. In recent years, adolescents have come to perceive marijuana to be relatively less harmful than it was in the past.[7] Also, adolescents perceive e-cigarettes to be safer alternatives to

conventional cigarettes.[32,33] As a result, adolescents may refrain from smoking conventional cigarettes but initiate e-cigarette use and/or marijuana use due to their perceptions that these substances are relatively safer and socially acceptable.[5,7,32,33] Both e-cigarettes (because of nicotine content) and marijuana have addiction potential,[14,34] and concurrent use of both products may have deleterious effects on the developing adolescent brain.[7] Previous studies demonstrating association between e-cigarette and marijuana use are either not nationally representative or limited to adult population.[30,35,36] For example, one study found a positive prospective relationship between e-cigarette use and marijuana use among young Hispanic adults in California.[35] A similar association was reported in a study conducted among 8th-grade students in Oregon.[36] E-cigarette users, compared to non-users, were found to be more likely to progress to using other substances including marijuana after 1-year follow-up.[36] National studies that specifically investigate the association between e-cigarette and marijuana use among adolescent never-smokers of conventional cigarettes are warranted to determine whether e-cigarette use may constitute an emerging, direct pathway into marijuana use.

Additional risk and protective factors influencing marijuana use in the current policy landscape should also be identified in order to inform marijuana prevention efforts. Increasing legalization of marijuana sales and unrestricted advertising of e-cigarettes (which can be used to vape marijuana) constitute emerging challenges to efforts to reduce the burden of adolescent marijuana use. Perceived availability of marijuana and peer marijuana use are risk factors that may be indicative of easy access to marijuana among adolescents.[37,38] Investigating how these risk factors predict marijuana use, specifically among adolescent never-smokers of conventional cigarettes, will be an important first step in addressing adolescent marijuana use. Similarly, investigating the role of protective factors such as parental monitoring[39-42] and religiosity[43-45] may provide additional insights into best approaches to reduce the burden of marijuana use among US adolescent e-cigarette users who have never smoked conventional cigarettes.

Thus, the purpose of this study is to (1) examine the relationship between e-cigarette and marijuana use; and (2) investigate other risk and protective factors for marijuana use in a national sample of adolescent never-smokers of conventional cigarettes and the subsample of e-cigarette users who have never smoked conventional cigarettes.

Methods

Study Participants

Participants were 8th- and 10th-grade never-smokers of conventional cigarettes ($N = 12,743$) from 2014-2015 publicly accessible files of Monitoring the Future (MTF) surveys.[46] The adolescent never-smoker sample was determined by selecting participants who responded "no" to the survey question: "Have you ever smoked cigarettes?" We also excluded participants who responded "already tried" to the survey question: "If you have never smoked, do you think you will try smoking cigarettes sometime this year?" The sample population was restricted to participants who self-identified as white, black, or Hispanic because other racial/ethnic groups were classified as missing in the datasets available for use in this study.

Measures

The dependent variable was past 30-day marijuana use, measured via a single item: "On how many occasions (if any) have you used marijuana (weed, pot) or hashish (hash, hash oil) during the last 30 days?" Responses (1 = "0 Occasions"; 2 = "1-2 Occasions"; 3 = "3-5 Occasions"; 4 = "6-9 Occasions"; 5 = "10-19 Occasions"; 6 = "20-39 Occasions"; 7 = "40 or More") were dichotomized into no/yes, where "no" indicates "0 occasions" and "yes" indicates at least 1 occasion.

Independent variables were past 30-day e-cigarette use, perceived availability of marijuana, peer marijuana use, parental monitoring, and religiosity.

Past 30-day e-cigarette use. Measured using a single item: "During the last 30 days, on how many days (if any) have you used electronic cigarettes (e-cigarettes)?" Responses (1 = "None"; 2 = "1-2 Days"; 3 = "3-5 Days; 4 = "6-9 Days"; 5 = "10-19 Days"; 6 = "20-30 Days") were dichotomized into no/yes, where "no" represents "none" and "yes" represents at least 1 day.

Perceived availability of marijuana. Measured via a single item: "How difficult do you think it would be for you to get marijuana (pot, weed), if you wanted some?" Responses were: "Probably Impossible" (1), "Very Difficult" (2), "Fairly Difficult" (3), "Fairly Easy" (4), and "Very Easy" (5).

Peer marijuana use. "How many of your friends would you estimate smoke marijuana or hashish?" Responses: "None" (1), "A Few" (2), "Some" (3), "Most" (4), and "All" (5).

Parental monitoring. Measured via 4 items: (1) "My parents know where I am after school"; (2) "When I go out at night, my parents know whom I am with"; (3) "When I go out at night, my parents know where I am"; and (4) "When I go out on weekend nights I have to be home by a set time."

Responses ranged from never (1) to always (5). These items are similar to those used to assess parental monitoring in previous studies.[39-42] Responses were averaged such that higher values indicate higher parental monitoring. Reliability was satisfactory (α = 0.72).

Religiosity. Measured by averaging participants' responses to 2 items: "How often do you attend religious services?" (responses ranged from [1] "never" to [4] "About once a week or more") and "How important is religion in your life?" (responses ranged from [1] "Not important" to [4] "Very important"). Reliability was satisfactory (α = 0.78). These items are similar to those used in previous studies.[43-45]

Control Variables

Risk-taking propensity. Measured via 2 items: "I get a real kick out of doing things that are a little dangerous" and "I like to test myself every now and then by doing something a little risky." Responses were on a 5-point scale ranging from (1) "Disagree" to (5) "Agree." Responses were averaged with high values indicating high risk-taking propensity (α = 0.76).

Paid employment. Measured using a single item: "On average over the school year, how many hours per week do you work in a paid job?" Response was on an 8-point scale ranging from (1) "none"; (2) "5 hours or less"; (3) "6-10 hours"; (4) "11-15 hours"; (5) "16-20 hours"; (6) "21-25 hours"; (7) "26-30 hours"; to (8) "more than 30 hours per week."

Sociodemographic variables. Participants' race/ethnicity was coded into white non-Hispanics, black non-Hispanics, or Hispanics; sex was indicated as male or female; grade was either 8th or 10th; and urbanicity was coded into rural or urban. Parent education level was measured on a 6-point scale ranging from 1 = "completing grade school or less" to 6 = "graduate or professional school after college." The average of both parents' education levels was used as an indicator for socioeconomic status (SES). Single parents' education level was used to indicate SES for participants with single parents.

Statistical Analysis

We used chi-square test of independence to assess bivariate associations between e-cigarette and marijuana use. Multivariable logistic regression was then conducted to examine how e-cigarette use and other independent variables relate to marijuana use while controlling for confounders. Two regression analyses were performed, the first among the total sample and the second among only e-cigarette users. We applied MTF sampling weights to all analyses.[46] Chi-square test of independence was

conducted using SPSS complex samples. Multivariable logistic regression was performed using Mplus version 7.[47]

As is typical in survey samples, some data were missing due to item nonresponse. Amount of missing data on individual variables ranged from 0%-23.7%. Overall, approximately 8.5% of data were missing. Missing data were handled using full information maximum likelihood (FIML). FIML is an alternative to listwise deletion when some participants are missing information on some variables. FIML retains participants in the dataset and uses all available data they provided to estimate relationships, thereby limiting bias that may be introduced by dropping the participant from the analysis completely.

Results

Descriptive statistics show that 5.2% (95% CI: 4.7-5.6) and 5.6% (95% CI: 5.2-6.1) of adolescent never-smokers of conventional cigarettes used marijuana and e-cigarettes, respectively, in the past 30 days. Prevalence of marijuana use was highest among Hispanics (7.1%, 95% CI: 6.1-8.4) and black non-Hispanics (6.9%, 95% CI: 5.6-8.4) compared to white non-Hispanics (3.9%, 95% CI: 3.5-4.5). Likewise, the prevalence of marijuana use was higher among e-cigarette users compared to non-e-cigarette users (24.2%, 95% CI: 20.6-28.1 vs. 3.9%, 95% CI: 3.5-4.4). The bivariate association between current e-cigarette and marijuana use was statistically significant, χ^2 (1) = 406.3, p<.0001. Sample descriptive statistics are summarized in Table 1.

In the total sample, after adjusting for other variables in the multivariable logistic regression model, the odds of being a current marijuana user were over 3 times higher among e-cigarette users than non-users (AOR = 3.14, 95% CI = 2.39–4.13, p<.0001). High perceived availability of marijuana and high peer marijuana use were also associated with increased likelihood of being a current marijuana user (AOR = 1.57, 95% CI = 1.37–1.80, p<.0001; AOR = 2.38, 95% CI = 2.14–2.66, p<.0001, respectively). High parental monitoring and religiosity were associated with lower odds of using marijuana, after adjusting for potential confounders (AOR = 0.65, 95% CI = 0.56–0.76, p<.0001; AOR = 0.86, 95% CI = 0.76–0.97, p<.05, respectively). Logistic regression results are presented in Table 2.

The second analysis examined only adolescent e-cigarette users who had never smoked conventional cigarettes. After adjusting for other variables in the model, significant predictors of current marijuana use were peer marijuana use and perceived availability of marijuana (AOR = 2.34,

95% CI = 1.88–2.93, p<.0001; AOR = 1.37, 95% CI = 1.01–1.86, p<.05, respectively).

Table 1. Descriptive Statistics, Weighted, $N = 12{,}743$

Variables	Categories	Overall ($N = 12{,}743$)		% Marijuana user	% Marijuana non-user
		n	%		
Sex	Male	6114	48.0	5.1	92.4
	Female	6451	50.6	5.2	93.1
	Missing	178	1.4		
Grade	Grade 8	6716	52.7	2.8	95.0
	Grade 10	6027	47.3	7.8	90.3
Race/ethnicity	Black	2071	16.2	6.9	89.8
	Hispanic	2955	23.2	7.1	89.6
	White	7717	60.6	3.9	94.7
Urbanicity	Rural	2450	19.2	2.7	95.5
	Urban	10,292	80.8	5.8	92.1
Maternal education level	Less than high school	1265	9.9	6.3	90.5
	High school	2196	17.2	6.2	91.6
	Some college	1781	14.0	5.3	93.2
	College or higher	6079	47.7	4.7	91.3
	Missing	1422	11.2		
Paternal education level	Less than high school	1460	11.5	7.7	90.1
	High school	2797	22.0	5.6	92.2
	Some college	1466	11.5	3.7	94.4
	College or higher	4953	38.8	3.8	94.9
	Missing	2068	16.2		

				Marijuana user	Marijuana non-user
Marijuana use	Yes	658	5.2		
	No	11,818	92.7		
	Missing	267	2.1		
E-cigarette use	Yes	720	5.6	24.2	72.6
	No	11,035	86.6	3.9	94.4
	Missing	988	7.8		
Hours of paid employment	None	9960	78.2	4.8	93.3
	5 hours or less	1164	9.1	4.3	94.4
	6-10 hours	529	4.1	7.7	89.9
	11-15 hours	239	1.9	7.8	90.4
	16-20 hours	217	1.7	7.4	89.4
	21-25 hours	69	0.5	14.8	84.5
	26-30 hours	56	0.4	12.6	87.4
	>30 hours	97	0.8	17.3	78.6
	Missing	412	3.2		

	n	*Mean (SE)*	*Marijuana user* *Mean (SE)*	*Marijuana non-user* *Mean (SE)*
Perceived availability of marijuana	10,764	3.23 (0.02)	4.56 (0.04)	3.17 (0.02)
Peer marijuana use	11,693	1.83 (0.01)	3.53 (0.06)	1.73 (0.01)
Parental monitoring	9723	4.42 (0.01)	3.91 (0.04)	4.45 (0.01)
Religiosity	9927	2.75 (0.01)	2.45 (0.05)	2.76 (0.01)
Risk-taking propensity	11,603	2.81 (0.01)	3.39 (0.06)	2.78 (0.01)

Table 2. Multivariable Logistic Regression: Predictors of Marijuana Use Among 8th- and 10th-grade Never-smokers of Conventional Cigarettes and E-cigarette Users Only

	Past 30-day marijuana use, total sample (N = 12,743)		Past 30-day marijuana use, e-cigarette users only (n = 720)	
	AOR	95% CI	AOR	95% CI
E-cigarette use (Reference = No)	3.14***	2.39 – 4.13	---	
Perceived availability of marijuana †	1.57***	1.37 – 1.80	1.37*	1.01 – 1.86
Peer marijuana use †	2.38***	2.14 – 2.66	2.34***	1.88 – 2.93
Parental monitoring †	0.65***	0.56 – 0.76	0.80	0.59 – 1.09
Religiosity †	0.86*	0.76 – 0.97	1.07	0.82 – 1.40
Hours of paid employment †	1.08	0.98 – 1.18	0.91	0.76 – 1.09
Risk-taking propensity †	1.13*	1.02 – 1.26	1.17	0.96 – 1.44
Race/ethnicity (Reference = White)	---			
Black	1.99***	1.45 – 2.73	1.49	0.69 – 3.19
Hispanic	1.77***	1.32 – 2.36	0.70	0.40 – 1.21
Sex (Reference =Female)	0.90	0.73 – 1.12	1.04	0.65 – 1.66
Parent Education Level †	0.98	0.89 – 1.09	1.03	0.85 – 1.24
Urbanicity (Reference = urban)	0.70*	0.51 – 0.98	1.04	0.47 – 2.31
Grade (Reference = 8)	1.53**	1.20 – 1.97	2.12**	1.26 – 3.58

*p<.05; **p<.01; ***p<.001; SE: Standard Error; AOR: Adjusted Odds Ratio; CI: Confidence Interval.
† Higher scores indicate higher perceived availability of marijuana, higher peer marijuana use, higher parental monitoring, higher religiosity, higher hours of paid employment, higher risk-taking propensity, and higher parent education level.

Discussion

This study finds a positive association between e-cigarette use and marijuana use among adolescents who have never smoked conventional cigarettes. A sizable proportion of these adolescents use marijuana (5.2%) and e-cigarettes (5.6%), with 24.2% of e-cigarette users concurrently using marijuana. Consistent with prior studies examining predictors of adolescent marijuana use,[37-39,42,43,45] perceived availability of marijuana and peer marijuana use were major predictors of marijuana use, while parental monitoring and religiosity were protective against marijuana use in this national sample of adolescent never-smokers of conventional cigarettes. In addition to these established predictors of marijuana use, this study adds to the literature by documenting the positive association of e-cigarette use with marijuana use among adolescents who have never smoked conventional cigarettes.

Adolescents who refrain from smoking conventional cigarettes are still at risk of using either marijuana, or e-cigarettes, or both. Among these adolescents, those who use e-cigarettes are 3 times more likely (than those who do not use e-cigarettes) to also be marijuana users, after adjusting for potential confounders such as risk-taking propensity, paid employment, and sociodemographic variables. This study adds to the growing literature on the association between adolescent e-cigarette and marijuana use by demonstrating the association in a national sample of adolescent never-smokers of conventional cigarettes. Adolescents' perceptions of the harm associated with marijuana use are declining rapidly with the increasing legalization of marijuana.[1,5,48] These changing perceptions may further increase the risk of marijuana use among adolescents.[5,7]

Our findings suggest that today's adolescents are not necessarily starting their marijuana use trajectories with conventional cigarette smoking. It is possible that adolescents who avoid conventional cigarette smoking start to use e-cigarettes and then progress to marijuana use or vice versa. It is also possible that these adolescents may be using e-cigarettes to vape marijuana, as reported by previous studies.[24,25] Future longitudinal studies will be needed to ascertain the direction of the association between e-cigarette and marijuana use. Regardless, our findings suggest that adolescents who have never smoked conventional cigarettes, particularly e-cigarette users, are currently at risk of the potential addictive, health, and social consequences of marijuana use.

Building on findings from previous studies, this study also demonstrates the association of perceived availability of marijuana and peer marijuana use on self-marijuana use in a national sample of 8th- and 10th-grade never-smokers of conventional cigarettes. Marijuana remains a

controlled substance at the federal level,[2] and there are age-restriction policies in states where marijuana sales are legalized for medical and recreational purposes.[3,4] However, despite these measures, adolescents have high perceptions concerning the availability of marijuana, with 35% and 64% of 8th- and 10th-grade students, respectively, perceiving marijuana to be readily available in 2016.[1] High perceived availability of marijuana and peer marijuana use are indicators of easy access to marijuana and may reflect the changing societal attitude toward marijuana use.[37,38]

While tobacco control policies are becoming stricter and more universal,[49,50] marijuana-related policies are becoming more lax across the US.[5] The increasing legalization of marijuana sales across the country may influence adolescents' perceptions regarding ease of availability of marijuana and make them more susceptible to marijuana use.[37,38] Future studies should investigate the extent to which current changes in marijuana policies are influencing adolescent perceptions of, and engagement in, marijuana use.

Our study also highlighted 2 protective factors against marijuana use among adolescent never-smokers of conventional cigarettes—parental monitoring and religiosity. Previous studies have shown that parental monitoring is protective against a number of risky behaviors among adolescents, including marijuana use.[39-42] In this national study, we found that adolescent never-smokers of conventional cigarettes who had higher levels of parental monitoring—as indicated by high parental knowledge of adolescent's activities—were less likely to be current marijuana users.

Parent perceptions regarding the health risks of marijuana use may be changing with current societal norms;[51,52] and parents may also perceive adolescents who do not smoke conventional cigarettes or who use only e-cigarettes as low risk. Parents may reduce their monitoring behaviors for adolescents who are performing behaviors that are perceived to be low risk or not harmful. How changes in perceptions regarding marijuana and e-cigarette use influence parental monitoring of adolescent substance use should be investigated in future studies. Similarly, religiosity was associated with lower risk of marijuana use, which is in keeping with findings from previous studies.[43,45] Future studies should explore strategies through which religiosity can be harnessed to address adolescent risk behaviors generally and marijuana use specifically.

Limitations

This study is not without limitations. The robustness of some of our study measures was limited by our use of secondary data. For example, parental

monitoring was measured using a self-reported 4-item scale as opposed to more elaborate measures proposed by previous studies.[53,54] However, our study measures have been validated and used in prior studies.[39-42] Also, the cross-sectional nature of our study does not allow for causal inferences to be made from our findings. However, the national representativeness of our sample makes our findings generalizable to 8th- and 10th-grade never-smoker population of the United States. Future longitudinal studies are needed to investigate possible prospective associations between e-cigarette use and marijuana use among adolescents.

Conclusion

Marijuana use was strongly associated with e-cigarette use, with about a quarter of e-cigarette users being concurrent marijuana users. Adolescent e-cigarette users who have never smoked conventional cigarettes are particularly more likely than non-e-cigarette users to be current marijuana users. High perceived availability of marijuana and high peer marijuana use were significantly associated with marijuana use among these adolescents while parental monitoring and religiosity were protective. Future studies should further investigate the relationship between e-cigarette and marijuana use and the degree to which changes in marijuana legalization are influencing marijuana use among today's youth.

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